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DEPARTMENT OF DEFENSE
DEFENSE ATOMIC SUPPORT AGENCY
WASHINGTON 25, D.C.

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ADDRESS REPLY TO
THE CHIEF, DEFENSE ATOMIC
SUPPORT AGENCY

DASARA-4 926.24

2 OCT 1963

SUBJECT: Draft Minutes of the 23rd Meeting of the Panel on Radiological Instruments

TO: SEE DISTRIBUTION

1. The draft minutes of the 23rd Meeting of the Panel on Radiological Instruments are inclosed for your consideration.

2. It is requested that any comments or corrections be communicated to the Chief, Defense Atomic Support Agency, ATTN: LCDR Richard E. Peterson, USN, PRI Secretary, Washington, D. C. 20301, by 15 October 1963.

3. This correspondence is marked "FOR OFFICIAL USE ONLY" solely because of the addition of inclosure 1. When this inclosure is removed, protective markings will be cancelled.

FOR THE CHIEF:

ARTHUR MOREAU
CWO, W-4, USA
Asst Adj Gen

1 Incl
Draft Minutes

DISTRIBUTION:

Commanding Officer, U. S. Army Electronics Research and Development Laboratory ATTN: Mr. O. E. Johnson, Fort Monmouth, New Jersey 07703
Chief, Bureau of Ships, Navy Department, ATTN: Mr. G. N. Mahaffey, Washington D. C. 20390
AFWL, ATTN: Capt C. E. Harris, Kirtland AFB NMex 87117
Director, National Bureau of Standards, ATTN: Dr. L. S. Taylor, Washington, D. C. 20234
St. Procopius College, ATTN:, Dr. F. R. Shonka, Lisle, Illinois
University of Rochester, River Campus, River Road, ATTN: Dr. W. Bale, Rochester 20, New York
Brookhaven National Laboratory, ATTN: Dr. V. Bond, Upton, Long Island, New York
Director of Research, Office of Civil Defense, ATTN: Mr. R. B. Martin, Washington, D. C.

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Twenty-Third Meeting of the

Panel on Radiological Instruments (PRI)

17-18 July 1963

1. The twenty-third meeting of the Panel on Radiological Instruments was called to order at the Armed Forces Radiobiology Research Institute, National Naval Medical Center, Bethesda, Maryland by the Temporary Chairman, Dr. F. R. Shonka, at 0900 on 17 July 1963. The following persons attended the meeting:

Name	Organization	PRI Affiliation
Dr. L. S. Taylor	National Bureau of Standards	Chairman
Dr. F. R. Shonka	St. Procopius College	Member
Dr. W. F. Bale	University of Rochester	Member
Dr. V. Bond	Brookhaven National Laboratory	Member
Mr. G. N. Mahaffey	Bureau of Ships	Navy Member
Capt. C. E. Harris	Air Force Weapons Laboratory	Air Force Member
Mr. O. E. Johnson	Electronics Research and Development Laboratory	Army Alternate Member
LCDR R. E. Peterson	Headquarters, DASA	Secretary
Mr. R. B. Martin	Office of Civil Defense	OCD Representative
Col. J. T. Brennan	Armed Forces Radiobiology Research Institute	
LCOL J. J. Franaszek	Armed Forces Radiobiology Research Institute	
Mr. K. F. Sinclair	Naval Radiological Defense Laboratory	
Mr. C. S. Hollander	Bureau of Ships	
Mr. A. M. Grosso	Naval Applied Science Laboratory	
Mr. A. Clark	Naval Applied Science Laboratory	
Dr. T. S. Mobley	Air Force Weapons Laboratory	
Capt. M. A. Quaife	Air Force Weapons Laboratory	
Dr. H. O. Wyckoff	National Bureau of Standards	
LCOL J. B. Young	Headquarters Army Medical R & D. Command	
Mr. H. P. Whitten	Army Combat Development Command, CBR Agency	
Mr. C. Siebentritt	Officer of Civil Defense	
Mr. T. P. Loftus	National Bureau of Standards	
Mr. A. S. Levenson	Bureau of Ships	
Dr. E. L. Alpen	Naval Radiological Defense Laboratory	

2. Col. J. T. Brennan welcomed the Panel to AFFRI. He explained that AFFRI is a tri-service organization which serves as a radiobiology laboratory for the three services. It considers the radiation hazards to personnel which confront the services now and those to be anticipated in the future. With respect specifically to Radiac instruments; AFFRI has a Radiac working group under LCOL Franaszek. This group does not work with the design of instruments as such, but studies such questions as the accumulation of errors resulting when Radiac instruments are used under battle conditions.

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3. The Secretary furnished each member of the panel with a copy of the revised PRI Charter dated 10 May 1963. He explained the changes which it had been necessary to make in the 1957 PRI Charter in order to comply with applicable Department of Defense directives governing the continuance of panels. The principal change is that the chairman must be designated by Chief DASA, rather than elected by the panel members.

4. The question of alternate members from the various services was raised by the Secretary. Captain Harris announced that Mr. Murphy of AFWL would be designated by the Air Force as the Air Force alternate member. Mr. Johnson of ELRDL will be the new Army alternate member to replace Mr. Sills. No alternate Navy member has been selected.

5. The Secretary announced that Dr. L. S. Taylor, who had accepted PRI membership as a replacement for the late Dr. Failla, was designated by Chief, DASA to be the new PRI chairman.

6. The Secretary read the summarized minutes of the previous meeting. They were accepted with the following corrections:

a. Dr. Shonka stated that paragraph 5 on page 6 should indicate that he was doing nothing more than carrying out the unanimous wishes of the panel in determining personally who might be available, in order that DASA might formally invite a replacement to fill the vacancy left by the late Dr. Failla.

b. Captain Harris said that in paragraph 3.c.1 on page 4, the response time of the SEMIRAD dosimeter should be shown as 10^{-8} seconds rather than 10^{-10} seconds.

7. In response to a question by Dr. Bale, a short discussion was held as to the present status of the recommendations made at the January meeting. The Secretary stated that PRI meetings are now being held on a twice a year basis as recommended. He said that under Article III.D of the revised PRI Charter, provision is made for OCD to designate a representative to attend panel meetings. The Service and OCD representatives stated that the present status of the other recommendations would be discussed during their individual presentations.

8. Dr. Mobley and Captain Quaife of AFWL discussed their work on the Biologic Effects of Pulsed Neutron Irradiation in Large Animals. A summary of their discussion of their work is included in Inclosure 1.

9. Mr. Mahaffey, assisted by Mr. Sinclair, Mr. Clark, Mr. Grosso, and Mr. Hollander, discussed the Navy Radiac Program. Their remarks are summarized in Inclosure 2.

10. The first day of the meeting was concluded with a tour of the AFFRI Triga Reactor and other facilities followed by a short discussion of the method of correlation of biologic exposures made using the AFFRI Fast Neutron Exposure Room and those resulting from exposure of tissue equivalent phantoms at the BREN Tower.

11. A discussion was held concerning the desirability of providing for classified discussion at future PRI meetings. Since it appears that Confidential or Secret discussions may be desirable for portions of future meetings, and all PRI members hold adequate security clearances, it was agreed if any member wishes discussion of material which is classified included in the agenda for a future meeting, he should contact the Secretary several weeks prior to the meeting so that the necessary arrangements can be made. It was suggested that in preparing the minutes of any such meeting, the classified portions should be separated from the rest of the minutes for convenience in handling.

12. As a result of a discussion held concerning the best time and place for the next PRI meeting, the panel was invited to meet at NRDL in San Francisco. 13 and 14 January 1964 were tentatively selected as the dates for the next meeting.

13. Mr. Johnson of ELRDL discussed the Army Radiac Instrument Development Program. His remarks are summarized in Inclosure 3.

14. Mr. Murphy and Captain Harris of AFWL discussed the Air Force Radiac Program. Their remarks are summarized in Inclosure 4.

15. Mr. Martin discussed the Civil Defense Radiac Program. A summary of his remarks is included as Inclosure 5.

16. Dr. Wyckoff of NBS discussed the X and gamma ray standards at the National Bureau of Standards. A summary of his remarks is included as Inclosure 6.

17. The matter of radiation quantities and units was discussed in view of the examples of loose and incorrect usage which had been noted at various times earlier in the meeting. The panel was referred for guidance to NBS Handbook 84, which contains the ICRU recommendations on units. The question as to the adequacy of presently agreed upon radiation units for military purposes was also raised, especially where neutron measurements are involved. It was suggested that it might be appropriate to request the assistance of either the National Committee on Radiation Protection and Measurements, or the International Commission on Radiological Units and Measurements in this matter. Dr. Taylor said that he would look into these possibilities.

18. The question of calibration and calibration geometry was raised by Dr. Wyckoff. A short discussion of the requirements for calibration was held, but no definite conclusions were reached.

19. The panel again discussed the past and future roles of the PRI, as had been done at the 22nd meeting. The concensus was that continuation of the panel is essential for the following reasons:

a. The panel plays an important role in the exchange of radiac information between the services and the various research activities involved.

b. Panel members provide expert advice which is extremely valuable to the DOD members of the panel.

c. The panel is, potentially at least, very valuable in working toward standardization of radiac instruments within the DOD. This can perhaps be done partially through consolidation and standardization of requirements. For example, since the OCD purchases very large quantities of instruments at a time, it acquires them at a substantially lower unit cost than the Services. If the Services and OCD can jointly purchase radiacs built to the same specifications, considerable savings to the government should result.

20. Since part of the problem of consolidation of requirements bears on the question of the required accuracy of radiacs, a discussion of this subject was held. It was suggested that some of the accuracy requirements may be unnecessarily high, particularly for instruments designed to measure low doses and dose rates. At higher doses and dose rates, accuracy is more important, in spite of the operational and biological uncertainties which enter into use of the data obtained. The importance of designing instruments which will give reproducible results was also brought out.

21. The panel next considered further the question of whether or not there are an unnecessarily high number of different types of radiacs within the DOD. It was suggested that the number of instruments listed in DASA 1243, "List of Military and Civil Defense Radiac Devices", tends to show that this is the case. It was suggested that the situation can be improved through adoption of more versatile instruments so that some existing special purpose instruments can be eliminated.

22. It was suggested that the panel can be more effective in the future by concentrating on one or two major problems per meeting, rather than briefly touching on a wide variety of subjects. The suggestion was made that for the next PRI meeting one full day be devoted to neutron measurement problems.

23. Discussion of standardization of instruments brought general agreements that a greater degree of standardization is a desirable goal. It was suggested that such items as pocket dosimeters and chargers might be relatively easy to standardize, assuming the military requirements and specifications can be coordinated. It was also pointed out that there are indications that the Defense Supply Agency is planning to centralize procurement in the Radiac Federal Stock Class, 6665, which may be a partial solution to this problem.

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24. In further discussion of items which the panel would like to have included for the next meeting, the following agenda items were offered:

a. Neutron measurement problems - instruments and dosimetry, including specifically how neutron dose should be measured for military purposes. (One full day to be devoted to this item.)

b. Setting of operational requirements for radiac devices.

c. Range requirements for general purpose radiacs.

d. Brief reports of recent developments (to include a summary report by the Navy on the Thermoluminescent Dosimeter).

25. The formal recommendation made at the 22nd PRI meeting concerning quality control of Civil Defense Radiac Instruments was discussed further. Mr. Martin of OCD reported that the situation was now very much improved. Mr. Siebentritt of OCD, who had taken over this aspect of the OCD Radiac program just prior to the last PRI meeting, now has an extensive quality assurance program in operation including laboratory tests and testing of instruments from the assembly lines.

26. The meeting adjourned at 1630 hours on 18 July 1963.

Richard E. Peterson

RICHARD E. PETERSON
LCDR, USN
Secretary, PRI

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SUMMARIZED REMARKS OF DR. T. S. MOBLEY, AFWL

METHODS OF NEUTRON DOSIMETRY AT THE AIR FORCE WEAPONS LABORATORY (AFWL):

In as much as all neutron dosimeters must ultimately be compared with neutron fluxes experimentally determined utilizing foil activation and fission foil methods, we at the Air Force Weapons Laboratory have adopted the threshold detector system as developed by Hurst et al and Reinhardt and Davis. Choice of the threshold detector system was also influenced by the availability of a pulsed reactor as a source of fission spectrum neutrons. The neutron doses reported in this paper are based on first collision neutron dose as determined by means of the Hurst threshold detector system. The first collision tissue dose from fast neutrons was calculated from the integrated fluxes determined from the threshold foils following the methods of Sayeg, et al and Humphreys, et al.

SANDIA PULSED REACTOR:

The Sandia Pulsed Reactor is a bare cylindrical, enriched uranium metallic assembly similar to the Los Alamos Scientific Laboratory's Godiva II critical assembly. The critical mass is a right circular cylinder with a spherically shaped top. A nine and one-half inch diameter perforated aluminum screen surrounds the fuel assembly. The center of the fuel assembly is located sixty inches from the reactor room floor.

The Sandia Pulsed Reactor (SPR) may be operated under steady state conditions or pulsed operation. All data reported in this paper were obtained under pulsed operation. A burst producing a 110^{o}C temperature rise in the fuel material yields 2 x 10^{16} fissions with a fifty microsecond pulse width at half maximum height.

AIR AND IN VIVO DOSIMETRY PACKAGES: (Fission Foils and Boron Ball with Cadmium Cup)

Threshold foils were used to measure the number of neutrons in five energy regions. The thermal flux was determined by exposing two mil thick bare gold foils and gold foils surrounded with a twenty-five mil thick cadmium cup. The fast neutron flux was determined through the use of Pu-239 to measure neutrons in the energy range of 4 kev to 750 kev; Np-237 to measure neutrons in the range of 750 kev to 1.5 Mev and U-238 to measure neutrons in the range of 1.5 Mev to 2.5 Mev. Sulfur pellets were used to measure the neutron flux above 2.5 Mev.

Plutonium-239 has a high thermal neutron fission cross section, thus the thermal neutrons must be removed in order to make it a suitable threshold detector. A Boron-10 shield was employed to remove the thermal neutrons. The B-10 shield was designed so that regardless of the direction of the incident neutron the desired thickness of B-10 was penetrated by neutrons in reaching the cavity in which the fission foils were placed. The cavity was lined with a 25 mil thick cadmium cup to capture any neutrons moderated by the boron shield.

COUNTING SYSTEM

The gamma activity was measured in the fission foils and the gold foils by means of a Packard Instruments Sales Model 410A pulse height analyzer and scintillation detection head consisting of two four inch by two inch sodium iodine thallium activated crystals. The detectors were positioned with respect to each other by a spacer assembly consisting of a sample slide and lead filter. The lead filters are required

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to reduce the background for Np-237 counting. Np-237 has a soft gamma background which is effectively filtered out by a 5/8 inch thick lead filter.

In order to make accurate measurements with scintillation counters of the gamma activity induced in the fission foils, it is necessary to maintain a constant bias level. The fission foils were counted at a discriminator setting equivalent to 1.2 Mev to obviate the count due to the 1.0 Mev gamma from Np-238 produced by neutron capture by Np-237.

Cesium-137 was employed as a gamma-ray source for standardizing the system. Standardization was accomplished by adjusting the gain so that at a discriminator setting of 33.0 volts all pulses of a height greater than those due to the total absorption of the 0.661 Mev gamma rays are accepted.

The thermal neutron flux was determined by scintillation counting of the bare and cadmium covered gold foils and taking the difference in their activation. The gold foils were counted on the fission foil counting system after replacing the one-quarter inch thick lead shield with a 1/16 inch thick aluminum filter to eliminate the 0.96 Mev gold-198 beta.

Sulfur pellets three quarters inch in diameter by one quarter inch thick were beta counted in a gas flow proportional counter.

CALIBRATION:

The fission foils and gold foils were calibrated by exposure to the known thermal flux at Los Alamos Scientific Laboratory's Omega East Reactor. Hurst et al have shown that the decay rate for fission products is the same when the fissions are produced by either fast or thermal neutrons. Absolute calibrations were accomplished with thermal neutron irradiation of a 0.1 gram Pu-239 and Np-237 and U-238 equivalent foils. The equivalent foils are mixtures of Pu-239 and U-235 of the proper ratios such that they will decay like Np-237 and U-238 but have the effective cross sections of Pu-239. Gold foils were exposed to the known thermal flux of the Omega East Reactor. Fission foils and gold foils were counted the Air Force Weapons Laboratory on the previously described counters. A sulfur pellet calibration was obtained by exposing the sulfur to the known flux of 14.1 Mev neutrons from the Cockcroft-Walton accelerator at LASL.

The radiations from a nuclear reactor always contain some gamma radiations as a contaminant. Pulsed reactors of the Godiva type, however, produce significantly fewer gamma rays. Moderated reactors frequently have neutron to gamma ratios of the order of one to ten or more. The SPR, however, has a neutron to gamma ratio of approximately seven to one. Gamma dosimetry was accomplished during the investigations reported herein. High atomic number radiophotoluminescent (RPL) glass rods were used to measure the gamma dose. Calibration exposures were performed by exposing the RPL dosimeters to a 100 curie Cs-137 calibration source. A calibration graph was constructed plotting measured fluorescence following exposure against known gamma dose. The known sensitivity of the RPL dosimeters to thermal neutrons necessitated exposure of the glass rods in a lithium-lead can containing an inner lining of glass for secondary electron equilibrium. The RPL dosimeter containers were fabricated at LASL and contained 21% Li^6F and 79% lead by weight. The containers were 8 mm outside by 11 mm in length. The RPL dosimeters were read after twenty-four hours on a Bausch and Lomb microdosimeter reader.

SET UP ON SPR EXPOSURE BOXES AND TABLES:

The reactor building housing SPR is a concrete hemispherical shell fifty four inches thick. It has an inside diameter of 30 feet and a maximum height of 20 feet. Preliminary neutron flux measurements by the Biomedical Section demonstrated that at distances beyond one and one-half meters a uniform flux was obtained at distances ranging from three feet to six feet above the reactor room floor.

The exposure boxes were of wood frame construction and prevented lateral or front to back movement of the experimental subject as well as ensuring the complete restraint of the animal while in the reactor room. The restraining boxes were supported on a turntable such that the center of the animal was approximately sixty inches from the floor.

DOSIMETRY PACKAGES:

The in vivo dosimetry packages consisting of Pu-239, Np-237, and U-238 fission foils encased in a 25 mill thick cadmium cup inside a two inch diameter boron ball, three quarter inch diameter sulfur pellets and bare and cadmium covered gold foils and the lithium-lead can, were sealed in a plastic bag for protection from tissue fluids and rumen contents. The in vivo dosimetry package was surgically implanted into the abdominal cavity of the experimental animals by our veterinary surgeons. In the sheep and the goat the pack was attached posterior to the left kidney and sutured at the approximate intersection of the saggital and medial planes. In some, but not all animals, additional gold foils, sulfur pellets, and RPL glass dosimeters were placed in surgically prepared subcutaneous locations.

The neutron and gamma doses measured in the animal were compared with similar measurements made in air at two meters, at the body surface, and at the body exit surface. Following exposure, the internal dosimetry package was surgically removed and the subject was permitted to recover.

X-RAYS OF IMPLANTED DOSIMETERS:

Radiographs in the posterior-anterior and lateral planes were made before and following neutron exposure. The radiographs enable us to determine any shift of the dosimetry package following implanation. The radiographs will further assist in measuring the thickness of tissue intervening between dosimetry package and the entrance of the neutrons.

RESULTS OF DOSIMETRY MEASUREMENTS:

Forty-four separate measurements were made of the neutron and gamma dose as measured in air at the two-meter distance. The exposure boxes containing the experimental subjects were so positioned that the midline of the animal was two meters from the center of the fuel assembly. The fuel temperature rise during the bursts ranged from 93.8°C to 108.7°C. The experimentally determined fast neutron rad dose was 161 ± 5.5 rads. The gamma dose as measured by the RPL dosimeters was 33 ± 2.4 rad. The integrated thermal neutron flux was $1.32 \pm 0.11 \times 10^{10}$ n/cm^2. The total neutron and gamma dose measured in air at the two meters position was 194 rad. The dose from thermal neutrons was considered negligible (1 rad of thermal neutrons equivalent to a thermal neutron flux of 5.5×10^{11} n/cm^2) and is not included in the total dose calculation.

Table 1 shows the results of the entrance, internal, and exit fast neutron first collision dose. The figure in the parenthesis is the per cent of the entrance dose. It will be noticed that in several instances the internal measured dose is less than the exit dose. It is felt that the lower internal doses were due to the accuracy limits of the detector components, the location and orientation of the package within the animal, the variation in tissue densities and composition, and the perturbation of the neutron flux by the relatively large dosimetry package.

Measurements of the entrance and exit doses were made on eight sheep. The exit dose averaged 18% of the entrance dose. Four sheep had dosimetry packages in the mid-line with the results as shown. Entrance and exit doses were measured on three dogs, while internal packs were placed in two dogs. The high exit dose for the first dog is actually a measurement in air at this position. Although the dog was restricted in its movement this particular animal managed to lie down. Because of the position of the dosimetry package in relation to the animal the exit dose was considerably altered. This was also the case in one of the swine exposures. Alpen and co-workers have determined depth dose curves in a six inch tissue equivalent phantom exposed to simulated fission neutrons from a cyclotron. This approximates the size of the dogs used in this experiment. They found the exit dose to be approximately 25% of the first collision dose as compared to our findings of 29 to 32%. Alpen measured the midline dose in the phantom at approximately 53% of the first collision dose as compared to 33 to 45% in our findings.

THERMAL NEUTRON INTEGRATED FLUX:

Table 2 shows the thermal neutron integrated flux. Results tabulated in this table show that within the first few inches of tissue the neutron spectrum is being altered in passing through the medium. The increased number of thermal neutrons strengthens the argument for the increased gamma dose within the first few inches of tissue.

GAMMA DOSE:

Table 3 shows the gamma dose. The two major components comprising the gamma depth dose are the doses from the primary gammas from the reactor and the dose from the secondary 2.2 Mev gamma rays created within the animal by hydrogen capture of thermalized components of the original fast neutron flux. This table demonstrates the buildup of the gamma dose within the tissue. It can be seen that there is a marked increase, when compared to the entrance dose, in the subcutaneous measurements. The internal dose, approximately at the midpoint of the animal continues to demonstrate a dose higher than the entrance dose. At the point of exit the dose has fallen considerably.

The general trend of the gamma dose measurements and the thermal neutron dose measurements agrees with the published findings of Alpen and his co-workers.

CONCLUSIONS:

Within a single animal species there is fairly good correlation between the entrance and exit doses as measured by the described dosimetry packages. Variations

are certainly obvious in the data presented. It is believed that these are due in part to the different sizes of the animals within the same species and differences in burst temperatures. Additional internal dose measurements may vary due to (a) perturbation of neutron flux by the dosimetry package, (b) amount, configuration, and composition of attenuating tissues, (c) accuracy of the detecting foils, and (d) orientation of the detectors within the animal.

During the first two weeks in July internal dosimetry measurements were accomplished on four additional sheep. The results of these studies were too late for inclusion in the table but in the first experiment the two animals had midline doses that were fourteen and fifteen percent respectively of the entrance dose while in the experiment completed on 11 July the midline doses in two animals were seven and eight per cent of the entrance dose.

PROBLEM AREAS IN NEUTRON DOSIMETRY AT SPR:

To date the greatest single source of error in our findings has been the inability to precisely measure the depth of tissue between the dosimetry package and the entrance of the neutrons. With the recent acquisition of a diagnostic x-ray machine the precise location and orientation of the dosimetry packages following implantation and exposure is possible. In one of the recently completed experiments we observed a change in positioning and orientation of the foils following implantation. The size of the internal dosimetry package is a limiting factor. There are only a limited number of positions in which the package may be sutured. A microdosimeter of the size of the RPL dosimeters for gamma dosimetry is urgently required to further study in vivo neutron dose. Threshold foil techniques are time consuming and accurate to only about twenty per cent. A more reliable dosimeter sensitive to the entire spectrum of neutrons is highly desirable. Certain of the solid state detectors may in time prove reliable but at this time we have had less reproducible results with silicon diode neutron dosimeters than we have had with threshold foils.

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FAST NEUTRON DOSE (RAD)

	Entrance	Internal	Exit
Sheep			
	226	38 (17%)	43 (19%)
	215	52 (24%)	36 (17%)
	227	18 (8%)	39 (17%)
	194	43 (22%)	39 (20%)
Dog			
	187	89 (48%)	152
	178	*	58 (32%)
	195	64 (33%)	57 (29%)
Swine			
	180	56 (31%)	106
	199	40 (20%)	45 (23%)
Goat			
	227	27 (12%)	45 (20%)

* Not Done

Table 1

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THERMAL NEUTRON INTEGRATED FLUX

(x 10^{10} n/cm^2)

	Entrance	Subcutaneous	Internal	Exit
Sheep	1.83	4.53	2.27	2.01
	1.35	2.48	6.61	1.01
	2.52	1.42	1.29	1.50
	1.09	4.94	4.07	1.05
Dog	2.20	4.80	3.24	1.70
	1.91	3.11	3.50	1.78
Pig	1.37	3.14	2.02	1.99
	1.66	8.94	1.86	1.94
Goat	1.89	4.54	1.61	2.63

Table 2

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GAMMA DOSE (R)

	Entrance	Subcutaneous	Internal	Exit
Sheep				
	42	72 (171%)	62 (148%)	25 (60%)
	44		70 (159%)	28 (64%)
	48		56 (117%)	28 (58%)
	41		52 (127%)	23 (56%)
Dog				
	36	56 (156%)	63 (175%)	40 (111%)
	33	*	*	24 (73%)
	49	63 (128%)	56 (114%)	36 (73%)
Swine				
	54	77 (143%)	63 (117%)	47 (87%)
	45	83 (184%)	60 (133%)	29 (64%)
Goat				
	72	*	57 (79%)	37 (51%)

* Not Done

Table 3

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BIOLOGIC EFFECTS OF PULSED NEUTRON IRRADIATION IN LARGE ANIMALS
A REPORT OF PRELIMINARY FINDINGS

Summarized Remarks of Dr. M. A. Quaife, Captain, MC, USAF

The history of research into Biologic Effect of Radiation was initiated with the discovery of X rays by Wilhelm Roentgen (Germany) in 1895. In 1896 Henri Becquerel (France) discovered radioactivity in uranium ushering in the era of natural radioactivity. Two journals in the field of radiology have been published for approximately fifty years. From these sources and subsequently many others, considerable information on the effect of X and gamma ray irradiation has been documented. The biologic effect from 250 KVP X ray irradiation has become a standard baseline, in the field of Radiation Biology, for studies of biologic effect from other radiation energies and forms.

The area of biologic effect from neutron irradiation stands in rather sharp contrast to that of X and/or gamma irradiation. James Chadwick (England) discovered the neutron in 1932 although the existence of the neutron was suggested by Rutherford in 1919. Considerably less information on the biologic effect of neutrons, except for catarractogenesis, had been generated up to 1945. The major amount of information since the advent of nuclear fission has been obtained in small animals irradiated in a neutron flux contaminated with a quite high gamma component, i.e., water moderated reactors.

With the availability to us of the Sandia Corporation's SPRF reactor, the staff of investigators of the Biomedical Group, AFWL, undertook the deliniation of the problem of neutron biologic effect. The basic philosophy guiding our work in our assigned mission in delimation of radiation hazard to Air Force personnel is as follows:

Guidelines were offered to us by William Harvey over 300 years ago when he said, "I have oftentimes wondered and even laughed at those who have fancied that everything has been so consummated and absolutely investigated by Aristotle or a Galen or some other mighty name that nothing could by any possibility be added to our knowledge."

In dealing with radiant energy particularly ionizing radiation, we are dealing with the deposition of physical energy. In the investigation of human hazards, judgements, we feel, are best made by correlation of interspecies comparison with available human data. This correlation, of course, is a time honored one in the field of toxicology. The most valid information from the interspecies comparison it would seem, would be obtained by deposition of the physical energy of radiation in a living tissue volume approximating that of man. The experimental subjects utilized to date have

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been predominently Ovine (sheep) with some work in goats and swine. The smaller mammalian species (dog) has also been utilized in some studies. As will be pointed out later other factors than tissue volume predicate for the use of Ovis aries (sheep) as a primary aid in making judgements toward man from the interspecies comparison. Parenthetically, it may be mentioned that burros are now on hand and will receive exposure to pulsed neutron irradiation in the near future. The first study is planned to repeat the reported exposure to two burros to neutron irradiation at Oak Ridge.

The experimental protocol in this study has as its basis the comparison of the effect of pulsed fission spectrum neutrons with that of 250 KVP X irradiation. The parameters utilized to measure the biologic effect of irradiation are as follows: (1) Clinical studies consisting of routine examination with recording of such information as weight, temperature, epilation, etc., (2) Hematologic studies consisting of a complete hemogram including thrombocyte level and also determination of MCV and MCHC as well as cell size distribution utilizing an electronic cell size plotter, (3) Ferrokinetic studies using Fe^{59} are utilized as a direct measurement of hematopoietic function. The most valuable portion of this study has proved to be the plasma Fe^{59} clearance half time, and yields as an added benefit plasma volume, red cell volume, and whole blood volume, (4) Plasma protein studies using a Beckman Amine Acid Analyzer, (5) Gross and microscopic tissue pathology, (6) Mortality data in terms of acute effects with the arbitrary end point being 30 days.

The experimental design of the individual experiments which comprise this investigative effort are in general as follows:

Experimental subjects are selected to comprise as homogenous a group as is possible from the available subjects in the experimental animal colony. Such parameters as size, weight, sex and age are of prime importance in the initial selection of subjects. All subjects selected for experimental study are segregated in a holding pen within a closed environment approximately one week preceding the start of the experiment. During this period baseline data in the form of a general physical examination, hemogram, ferrokinetic studies, etc., are carried out to insure normalcy within the group and to serve as baseline values for the interpretation of subsequent data. The subjects are assigned at random to control and experimental groups for the conduct of the study. No drugs or anesthetic agents are used.

In the conduct of the experiment every effort is made to insure like treatment of control and experimental groups except for the experimental variable under study, i.e., radiation. As an illustration of the foregoing, all subjects are placed in exposure holding boxes prior to exposure and transported to the exposure site. All subjects remain in the exposure holding boxes for the same time and then are returned to their segregated holding pen.

1. Clinical Data. Initial epilation in sheep is evident by D + 5 and increases to 90-95% by D + 20

In general it appears that although neutrons are far more effective in epilation of sheep and initiation of vascularization of the cornea, they produce less acute clinical changes to the overall system than exposure to similar rad dosages of 250 KVP X ray. The same is true of dogs in the acute clinical changes in the overall system.

2. Hematologic Data. Neutrophill and lymphecyte numbers decreased rapidly after the exposures and the nonsurvivers of both types of irradiation showed changes of similar magnitude in both species. Appreciable recovery of white cells was noted at approximately 24 days past-exposure in the survivers of neutron irradiation only.

In both species there was a marked fall in thrombocyte level in the first weeks following exposure to both radiation forms. The decrease in thrombocyte level occurred somewhat earlier, i.e., one to two days in the dog, than that of the sheep and reached a maximum decrease earlier than the sheep. The nonsurvivers which received neutron irradiation in both species appeared to have an earlier fall of thrombocyte level than either the x-ray group or the surviving neutron irradiated group. This fall continued to death.

The survivers of X irradiation showed no recovery of thrombocyte level within the first 30 days and remained at extremely low levels observed in the second week post-exposure.

Recovery was noted in the subjects surviving neutron irradiation in both species as evidenced by a rise in thrombecyte level in the third week post-exposure. Again recovery was noted somewhat earlier in dogs than in sheep.

It is of interest to note that the temporal progression of the thrombocyte level in sheep is similar to that noted in humans following exposure to comparable doses of ionizing radiation. Evaluation of thrombocyte level with reference to time is a valuable adjunct in assessing the degree of damage caused by exposure to ionizing radiation. It also appears to be of value in predicting recovery especially in cases exposed to predominently neutron irradiation.

3. Ferrokinetic Data. Plasma iron clearance half time has been utilized as a parameter of measurement of the effect of wave and particle irradiation in the hematopoietic systems of sheep and dogs. This parameter has been utilized to compare the effect of each radiation form against an unirradiated control group as well as to compare the two types of radiation for their effect on the hematopoietic system

4. Amine Acid Analysis on Deproteinized Plasma.

5. Gross and Micro Tissue Pathology.

Comparison of tissue alterations in both species produced by exposure to 250 KVP X ray or pulsed fission spectrum neutron irradiation has shown a general similarity of response. However, the lungs of subjects exposed to fission spectrum neutrons are considerably more susceptable to peribronchial and perivascular pulmonary hemorrhage. The earliest histologic changes observed in dogs lungs occurred five days post-exposure, consisting of focal well demarcated areas of alveolar congestion, swelling of capillary endethelial cells and slight alveolar extravasation of red blood cells. These changes became more generalized by nine days post-irradiation and in addition there were focal areas of peribronchial extravasation of blood involving the right and left main stem bronchi. Subjects necrepsied on the 13th day post-irradiation revealed extensive perivascular hemorrhage involving large and small pulmonary arterial vessels. The blood appeared within the advential connective tissue and periarterial lymphatic spaces. Endethelial swelling was extremely marked in affected vessels, but the media appeared unremarkable. Peribronchial hemorrhage was also present adjacent to affected pulmonary arterial branches.

The pathegenesis of these alterations appears to be related to primary endethelial damage produced by pulsed fission-spectrum neutrons. An additional contributing factor is probably thrembocytopenia as the number of marrow megakaryocytes was found to be inversely proportional to the severity of intrapulmonary hemorrhage.

On the basis of the hematologic and ferrokinetic parameters there is certainly no more than a 1:1 relationship between similar rad dosages of pulsed fission-spectrum neutrons and 250 KVP X irradiation.

If epilation or eye changes are utilized as the parameter of effect, then the above relationship approaches infinity.

In the area of gross pathologic effect a notable difference is seen in the effect upon the fine arterial vasculature in the lung of subjects receiving neutron irradiation. Analysis of amine acids in deproteinized plasma has revealed the elevation of certain of the amine acids. This elevation of amine acid appears to vary as to specific type depending upon the type radiation, i.e., neutron or 250 KVP X ray.

Finally on the basis of the mortality data presented, pulsed fission-spectrum neutrons would appear to be approximately one-fourth as effective in producing acute mortality as a similar rad dose of 250 KVP X irradiation.

I wish to stress again that the major portion of this work is preliminary in nature.

NAVY RADIAC PROGRAM

By G. N. Mahaffey, Navy Member

The Navy's Radiac Program is divided into three major functional areas: analysis, research, and development. These are essential to the development of operationally significant Radiac Equipments for Naval Forces afloat and at shore establishments. The objective of the analysis task is to improve the military capability to deal with radiological involvement by providing radiac doctrine, by developing apparatus and standards for guiding radiac development, procurement, testing, and usage, and by performing suitability and acceptance tests on radiac devices. Objectively the research task is to investigate new electronic circuits, circuit components, and detectors for applicability to new and established radiac requirements. The objective of the development task is to provide radiac equipments and systems required by the Navy.

Some of the work presently underway in support of these tasks includes:

US NAVAL RADIOLOGICAL DEFENSE LABORATORY (USNRDL)

1. RECYCLING IONIZATION CHAMBER SYSTEMS - advantages for military applications include: accuracy, basic simplicity, flexibility, and reliability.

2. RADIAC CALIBRATION AND PERFORMANCE STUDIES - preparing a handbook to provide information (e.g. orientation and effect of operator) and guidance in field applications; and performance of high and low range radiacs (AN/PDR-43 and AN/PDR-27J) for cold weather operations by replacing JAN/BA-30 with E-95 batteries.

3. COMMAND AND CONTROL SYSTEM STUDY - investigation being made to define command and control requirements to cope with initial and base surge radiation involvement at sea. Radiological data system - NEWRADS - has been recommended and development started. As an interim capability recommendations will be made on using existing equipment now in the Naval service.

4. THE RDGI-1 TACTICAL DOSIMETER-RATEMETER - development nearing completion and intended to meet small ship and command post radiac requirements.

5. RESULTS OF FIELD TESTING THE ALPHA AN/PDR-56 RADIAC SET - large number recently tested under extensive field program. No failures, including light leaks, were experienced. Very good user reaction.

US NAVAL APPLIED SCIENCE LABORATORY (NASL)

1. RADAR X-RAY HAZARD METER - development nearing completion and intended to measure the X-ray component of the potential personnel radiation hazard from high voltage and high power radar equipments. Measures dose rates to 5000 mr/hr with ±15% accuracy for effective energies between 20Kev to 1.3 Mev.

2. AN/UDM-7 ALPHA RADIAC CALIBRATOR - development completed and first units fabricated which permit the calibration of alpha radiac sets and uses two Plutonium-239 alpha sources. Techniques developed at the Laboratory used in preparing the sources.

3. MODIFICATIONS TO AN/PDR-27J AND AN/PDR-45A RADIAC SETS FOR RANGE EXTENSION - circuit modification studies completed for increasing the range of the AN/PDR-27J to 2000 mr/hr and the AN/PDR-45A to 5000 R/hr. Interim capability to fulfill Bureau of Yards and Docks requirement to monitor operations of nuclear reactors in cold weather areas.

COMMERCIAL CONTRACT - EDGERTON, GERMESHAUSEN & GRIER (EGG)

1. THERMOLUMINESCENT DOSIMETER READER SYSTEM - development contract recently completed and the five hundred dosimeters and five readers to be used in obtaining operational statistics.

We are fortunate in having people with us today who are directly concerned with these problems. Complete coverage of the work at USNRDL will be given by Mr. Ken Sinclair; at NASL by Messrs. A Clark and A. Grosso; and Mr. C. Hollander, from BUSHIPS, will discuss the TLD System.

RECYCLING IONIZATION CHAMBER SYSTEMS

by K. Sinclair

The increased reliability, simplicity and flexibility of the recycling ionization chamber sensor makes it an attractive component for military radiac application.

This approach, originally developed by Wilson et al, some years ago, utilizes an ionization chamber detector, an electrometer and suitable recharging circuitry. Initially the chamber is charged to some suitable voltage biasing-off the electrometer tube; as radiation falls on the detector, the charge on it decreases until the electrometer tube begins to conduct, developing an output pulse. At the same time, the recharging circuitry is actuated and the chamber recharged in readiness for a new cycle. Each output pulse represents a pre-determined increment of dose.

The output pulse is a relatively low impedance signal and, since the electrometer tube can be sealed inside the ion chamber, there is no need for external high impedance wiring or switching.

The digital form of the output pulse permits straightforward electronic computation of either doserate or dose and simplifies data transmission. It also insures no-drift performance, a very desirable military radiac characterisitic.

Further, because of the low impedance digital output of these systems, detectors can be easily remoted using either hard wire or radio transmission.

The recycling ion chamber approach has been successfully used in the AN/SDR-1 Shipboard Radiac System, the IM-153 Alarm Dosimeter and the AN/PDR-63 (RGI-20) Multi-Purpose Radiac.

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RADIAC CALIBRATION AND PERFORMANCE STUDIES

By K. Sinclair

Studies are being implemented to improve the operational performance of existing radiac devices and to provide guidelines for future development. Results of these studies will be made available to users through the planned radiac handbook. The first section of this book, covering the AN/PDR-43, was recently completed. Significant new recommendations for this radiac were made on calibration and low temperature operation.

Calibration of radiacs is complicated by the non-uniform response of these devices as a function of orientation with and without operator. This problem has long been recognized but information sufficiently definitive to warrant specific recommendations regarding corrective measures has been unavailable. The Effect of the Operator Study was undertaken to provide this information and to furnish guidelines for future development.

Detailed data on the response of the AN/PDR-43 has been obtained showing an average response for a large number of different source-radiac positions approximately 20% low when the device is calibrated correctly according to existing instruction. Since the source distributions anticipated in military situations will probably approach the isotropic, a new calibration procedure has been recommended that will remedy this problem. One unusual aspect of the performance of this radiac was its relative freedom from operator effect in normal use. Consequently, special use instructions are not required.

Low temperature performance of the AN/PDR-43 was examined using standard BA-30 cells and the new alkaline-manganese system batteries. After storage at 25°C with BA-30 cells, useful battery life is approximately 2½ hours at -40°C. With the E95 alkaline manganese system dry batteries, however, life at this temperature exceeds 50 hours.

Additional sections of the radiac handbook, covering other current service radiacs, are now in preparation. Current plans include a loose-leaf format for the handbook that will permit updating previously published sections as required.

COMMAND AND CONTROL SYSTEM STUDY

By K. Sinclair

Studies are now nearing completion at USNRDL to better define the command and control requirements for radiological data at sea. On the basis of this work, a newly installed shipboard radiological data system - NEWRADS - has been recommended and development initiated. However, this equipment will be unavailable for some time and interim techniques and procedures must be provided in the near future. The necessary reassessment of existing military dosimetry to determine its area of applicability is now underway.

Particular stress is being placed on the high intensity gamma and neutron detection capabilities of the IM-143 and the DT-60. Previous work along these lines has been examined in some detail and summarized and some additional experimental work has been performed.

The IM-143 has been exposed to pulsed radiation at the TRIGA reactor in San Diego. Response to these Gaussian shaped pulses of milliseconds duration shows rate independance to about 10^6 r/hr. Fission neutron response in this exposure situation was about 40% of the true rad dose.

The DT-60 has been tested at gamma rates in excess of 10^{11} rad/hr with no detectable performance degradation. Fast neutron response appears to be less than 1% but the device has an exaggerated thermal response perhaps ten times the equivalent Co^{60} gamma response rad for rad.

Attention is also being given at this time to the field measurement problem. Since the dosimeters will be worn on the body and should provide meaningful data regarding biological hazard, some basic questions must be answered, viz., does midline dose correlate best with injury?; what is the difference in the effectiveness of multi-lateral and uni-lateral exposure?; how should the dosimeter be worn?; how should the neutron produced gamma component be taken into account?; etc. The answers to many of these questions are available but the development of a clear rationale taking into account all aspects of the system, i.e., source-operator-bio-effects-data utilization, remains to be accomplished. Consistency is of overriding importance here, otherwise predictions made on the basis of instrument data become worthless.

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<u>THE RDGI-1 DOSIMETER-RATEMETER</u>

By K. Sinclair

The RDGI-1 Radiac is intended for command purposes on small ships and for Marine Corps applications. It measures gamma radiation dose (0 - 10,000 rad) and doserate (0-10,000 rad/hr) and provides an adjustable alarm capability from 2 - 100 rad/hr. Provisions are being made to permit remoting the detector up to 200' from the main unit and to accommodate other accessory detectors.

The device weighs less than 3# and in its breadboard form is 4" x 4" x 7" long. It operates from two size "D" nickel-cadmium cells recharged by means of a built-in charger.

This instrument is now in the advanced prototype stage and completion is planned for this fall.

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FIELD TEST OF THE AN/PDR-56 RADIAC

By K. Sinclair

A number of AN/PDR-56 Alpha Survey Radiacs were recently field tested under operational conditions. Previous field work had been satisfactorily completed using laboratory and preproduction models of this instrument, but the test reported here was the first opportunity to examine production instruments in this manner.

Service personnel, previously untrained in the use of alpha radiacs, were used as monitors following brief indoctrination. The adequacy of this indoctrination is demonstrated by the fact that not a single window was lost during the course of the effort despite the fact that the unprotected instrument probe was placed in direct contact with the monitored surface.

The initial laboratory calibration of the radiacs held for all of the devices tested during the entire operation including transit. All calibration checks were within ±5% of the initial calibration. The integral thorium 232 source was felt to be an entirely adequate calibration source for this particular device on the basis of the field work.

No failures, including light leaks, were experienced during the course of the work and freedom from temperature and battery voltage dependence permitted extended operation within the calibration limits indicated above.

User reaction to the following features was favorable: the probe extension, the probe lock-on feature (permitting use of the instrument as a one-package device), the scale charging meter, the meter light and the auxiliary small probe.

Negative reactions were received on the following: meter fluctuations on X1 scale (long time constant equally objectionable), the inadequate carrying strap and insufficient scale color contrast.

Comparison of data from several alpha radiacs (including the '56) at a number of measuring points on concrete and dirt shows similar results. While not expected, it suggests that the field measurement problem may not be as difficult as originally supposed.

During the course of the laboratory calibration of the AN/PDR-56's the need for a more definitive window test became apparent. An intensity at the window of 3000 ft.-candles at 2800°K was found to adequately simulate normal field use in bright sunlight. Window replacement was readily managed by an untrained person as was the one potentiometer calibration procedure.

RADAR X-RAY HAZARD METER

By A. Clark

In radar equipments, the production of X-Rays is an undesirable by-product of the electronic devices which generate the microwave radiation. Most of the military radiacs in use are ineffective for surveying the pulsed, low energy X-Rays which are produced, usually with a concomitant microwave field. The Naval Applied Science Laboratory has developed a survey instrument which overcomes the disadvantages inherent in other instruments. The instrument measures dose rates over 4 full scale ranges of 5 to 5000 mr/hr with an accuracy of $\pm 15\%$ for effective energies between 20 Kev and 1.3 Mev. The detector is a plastic phosphor assembly (wafers of "Pilot B" and lucite loaded with silver-activated zinc sulfide) coupled to a 6199 photomultiplier tube. The electronic circuitry utilizes a d-c difference amplifier which drives a 20 μamp meter for read-out. Peak X-ray intensities of 25,000 r/hr are integrated without saturation effects and the instrument is unaffected by microwave energy in the x-band up to 50 mw/cm^2 and by magnetic fields up to 1 gauss at 30 Kc/s. The probe is provided with arc-over protection. A prototype model is described herein.

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ALPHA RADIAC CALIBRATOR

By A. Grosso

Until recently, a complex assortment of alpha standards was required to give a partial calibration to alpha radiac equipments. The Naval Applied Science Laboratory has designed, developed and fabricated the AN/UDM-7a Alpha Calibrator, which effects a complete calibration of all existing alpha radiac sets, utilizing two Plutonium-239 alpha sources.

The alpha sources of the AN/UDM-7a are approximately 12 inches in diameter, 1 mg per cm^2 thick and uniform to within $\pm 5\%$. A spectral analysis of these sources conducted by the National Bureau of Standards indicates that 90% of the alpha radiation emitted from these sources possess as energy greater than or equal to 4 MEV.

The procedure for fabricating the alpha sources is a simple one, requiring the addition of the radioactivity to a fixed amount of resin and alcohol. The resulting mixture is then poured on to a smooth, level plastic disc and allowed to dry.

Fifty AN/UDM-7a Alpha Calibrators were recently manufactured for the government, by a private contractor, with little or no difficulty. These calibrators are in the process of being shipped to sub-tenders and various radiac repair facilities.

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MODIFICATIONS TO AN/PDR-45 AND AN/PDR-27J

FOR RANGE EXTENSION

By A. Clark

Bureau of Yards and Docks have a requirement for instruments covering the ranges 0 - 2000 mr/hr and 0 - 5000 r/hr for use in monitoring reactor operations in Arctic areas. For interim use this requirement has been met by adding a fourth range to the AN/PDR-45A, utilizing an additional variable inductor and eliminating the "battery check" position. This enables the set to read up to 5000 r/hr. For the 0 - 2000 mr/hr range, the AN/PDR-27J has been found to already possess this capability if the calibration potentiometer for the 0 - 500 mr/hr range is set near to its lowest value of resistance. The set does not saturate until a value of 2500 mr/hr is reached.

THERMOLUMINESCENT DOSIMETRY SYSTEM

By C. Hollander

The phenomenon known as thermoluminescence, the emission of light on heating a solid to a temperature below the point of incandescence, has been known for more than two centuries. The use of an agent such as X and gamma radiation to cause trapping of electrons in solids also dates far back. However, it wasn't until personnel at the U. S. Naval Research Laboratory developed a suitable phosphor that thermoluminescence came into its own as a dosimetry device. The phosphor developed by NRL is manganese activated calcium fluoride.

The TLD (an abreviation of thermoluminescent dosimeter) performs in a very simple manner; X or gamma radiation incident on the phosphor is stored as trapped electrons which are bound such that relatively high temperatures (energy) are necessary to release them. The released electrons subsequently recombine with charges of the opposite sign and emit light (energy) in the process.

The development of the Calcium Flouride phosphor and a primitive type reader, although a giant step forward, was a far cry from a dosimetry system useful to the Navy in fleet operations. However, the potential for the TLD system as a replacement to the film badge dosimetry system was by this time evident.

Film badge dosimetry deficiencies corrected by the TLD system included insensitivity to 1/3 weekly tolerance doses and below, development space, non-sensibility , directional response, and limited range.

Edgerton, Germeshausen and Grier, Inc., was awarded a contract during 1961 to develop a TLD system compatible with military requirements, such development to be completed in two years. The development has now been completed and tests are being conducted. As of this date, tests indicate the system will adhere to every requirement placed on it by the applicable specification. Some of the more prominent features are:

Range from 4 mr to 10 kr within a $\pm 20\%$ accuracy
Reuseability in excess of 100 times
Storage to 60 days without significant loss of dose data
Permanent record information including automatic printout of 10^8 different identification code numbers.

Field operational tests will commence approximately 15 August 1963.

ARMY RADIAC INSTRUMENT DEVELOPMENT PROGRAM
Summarized Remarks of Mr. O. Johnson, ELRDL

1. Tactical Survey Meter and Vehicular Radiac System, AN/VDR-1(XE-2)

Radiac Set AN/VDR-1(XE-2), which is in the development stage, detects and reads gamma radiation in the range of 100 millirads/hr to 1000 r/hr. The set will consist of Radiacmeter IM-133(XE-2), multiple probes, and mounting hardware. The Radiac Set is intended to enable personnel to make vehicular or dismounted surveys of radiologically contaminated areas. Ambient gamma radiation may be detected within and outside of the vehicle making the survey. For dismounted survey, the radiacmeter may be easily removed from the vehicle and carried about the user's neck by means of a strap leaving the user's hands unoccupied. It is self-contained using rechargeable batteries as the power source. Military BA-30 batteries may also be used and provision will be made for utilizing vehicular power sources.

One of the detectors will be mounted external to the vehicle and will be used when making rapid vehicular survey. A detector embodied within the radiacmeter itself, will be used for dismounted survey. The application of micro-miniaturization, encapsulation of components, and use of semi-conductor devices will materially reduce the size and weight of the radiac set and enhance its reliability.

The wide dynamic range of this instrument can easily be extended to range from 1 millirad/hr to 1000 r/hr. By including a plug-in detector with a side window, personnel and material may be monitored for contamination; read-out being beta or gamma. The read-out will be a meter presentation with this additional range.

The Radiacmeter IM-133(XE-2) will incorporate a presettable alarm feature. Although the MC's call for an audible alarm, it is felt that a visual alarm would be of greater value as vehicular noise, especially that of tanks could drown out the alarm.

The extending of the range and incorporation of a hand-held plug-in detector will make this instrument extremely versatile. In fact, it will serve the purpose of a Tactical Monitoring Instrument as well as a survey instrument. The design, construction, production, and logistics savings accrued from the procurement of this one instrument will be extensive.

2. Aerial Radiac Set AN/ADR-6

Aerial Radiac Set AN/ADR-6 is an airborne equipment for radiological reconnaissance and surveillance of ground areas contaminated by radioactive fallout. It measures and records dose rates of gamma radiation with a dynamic range from 1 to 1000 rads/hr at the ground level. In conjunction with a radar altimeter the aerial radiac set performs automatic in-flight altitude correction in an operational altitude range from 200 to 800 ft. In this way the aerial dose-rate measurement is automatically increased by a proper factor (air-to-ground correlation factor (AGCF)) to account for the reduced gamma intensity at a particular altitude and to make the meter and recorder indicate approximate ground radiation levels. In case no radar altimeter is available with the

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aircraft, the automatic altitude correction circuit can be disengaged and the instrument simply measures and records the aerial radiation levels. Altitude correction would then be accomplished manually in the process of data reduction on the ground, based on an assumed constant ground clearance of the aircraft.

The aerial radiac set also provides a presettable alarm. A telemetry output is available and can be used with commercial telemetry links or with forthcoming Army telemetry equipment.

AN/ADR-6 will be compact. Its weight, including recorder, but excluding altimeter, will not exceed 30 pounds. It can be readily installed and flown in Army aircraft of the observation and utility type as well as drones. The power requirement is approximately 10 watts, at 28V dc (no batteries).

The detector is of the scintillation type, using a small size photomultiplier and plastic phosphor. Accuracy (probe-to-readout) is within ± 15%, on a 3-decade logarithmic scale. Recorder response speed is 0.2 seconds per decade change in radiation intensity.

The current aerial radiological detection method (FM-3-12) is a primitive and tedious process, requiring the operator to take readings from a standard radiacmeter at regular intervals and to note them on a chart (clipboard method). In addition, the pilot is expected to maintain a constant nominal altitude, which is difficult in practice.

AN/ADR-6 will greatly simplify this procedure in that it mechanizes the bookkeeping by means of a chart recorder and eases the requirements on the pilots, since altitude variations are automatically corrected for. Thus, demands on endurance and alertness of personnel are reduced considerably and both operator and pilot can concentrate on navigation and maintenance of constant ground speed, which is important for accurate results.

Because of the fast instrument response (0.2 seconds per decade intensity), reasonable ground resolution will also be obtained for fast flying surveillance aircraft with ground speeds up to 500 knots (250 m/sec). The limitation lies primarily in the navigation accuracy, i.e., in the ability to relate the recorded radiation profiles to specific flight legs on a map. In combination with future standard Army data links, radiological data can be telemetered in real time to the CBR center on a "plot as you fly" basis which means the complete isodose map is rapidly available to the commander.

Development of an Aerial Radiac Set is about to be completed by USAELRDL (AN/ADR-6(XE-2).) Two development models will undergo environmental and radiation testing at USAELRDL each using a different recorder.

Laboratory tests over a point source are planned for July 1963 in conjunction with a Minneapolis-Honeywell 7091 radar altimeter.

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Laboratory tests with radar altimeter over Pelham range, Ft McClellan, are planned for September 1963. Helicopters of the H-19 type will be used for the laboratory tests.

3. Tactical Dosimeter, IM-184/UD

Radiacmeter IM-184/UD is a tactical dosimeter capable of recording total gamma and neutron dosage in rads from the spectra and from the ultra-high initial dose rates resulting from nuclear detonations, or from fallout. The IM-184/UD is a fountain-pen-size quartz-fiber dosimeter with a tissue-equivalent vacuum chamber operating on the SEMIRAD (Secondary Electron Mixed Radiation Dosimeters) principle. Primary electrons resulting from gamma radiation and recoil protons resulting from neutron radiation cause low-energy secondary electrons to be emitted from the walls of the vacuum chamber. These secondary electrons are collected, causing the quartz-fiber electroscope to discharge. The instrument reads the total cumulative neutron and gamma dosage in rads delivered to the tissue-equivalent chamber and is dose-rate independent. SEMIRAD neutron and gamma-rate instrumentation have been successfully used to make basic measurements at nuclear-weapons test detonations. This principle represents a major breakthrough in the state of the art.

The sensitive elements of present quartz-fiber dosimeters such as the IM-93 are ionization chambers. Since ionization chambers are rate-dependent, the nuclear radiation delivered at rates above about 10^5 rads/second which occurs during approximately the first millisecond after a nuclear detonation is not recorded. Thus all neutron radiation and a fraction of the initial gamma radiation are not recorded by the IM-93. The IM-184/UD which incorporates a SEMIRAD vacuum chamber will not experience rate dependence below 10^{10} rads/second and thus will satisfy military requirements.

Twelve EDT models are planned to be available for laboratory tests in October 1963. These models available from Air Force on a coordinated development basis.

150 service test models purchased jointly with Air Force in FY 64 and submitted for service test September 1966.

4. Individual Dosimeter System: Detector, Radiac DT-236( )/PD and Computer-Indicator, Radiac CP-696( )/UD

The individual dosimeter indicates total cumulative gamma and fast-neutron dosage in the range of 1-1000 rads by means of separate elements. Both elements are small, solid-state devices. The neutron device is a wide-based silicon-junction diode and the gamma device is a silver-activated phosphate-glass pellet. Both elements are encased in a plastic card which is worn on the dog-tag chain. Reading is indirect and a readout instrument is required. The gamma element is read by the fluorimetric method, using UV excitation, and the neutron element is

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read by measurement of its forward voltage drop at constant-current conditions. Both elements are energy and rate independent. The system reads true dosage within 20 percent accuracy. Provisions are made for recording serial numbers, dosage, dates, etc., on computer cards.

The Army does not have an individual dosimeter. This device will be used as an administrative dosimeter to supplement tactical dosimeters; it provides a permanent record of dosage. It also has a neutron capability; existing dosimeters do not. Its small size permits it to be worn constantly in standardized positions.

Experimental models of the neutron diode have been obtained from previous contracts. Two contracts are now being processed, a research contract to improve the uniformity of the neutron diode and a contract to provide engineering design test models of the entire dosimeter and reader. Service test models will be purchased in FY 65 for service test in July 1966.

5. Tactical Survey Radiation Monitor, IM-145

The IM-145 is a wide-range hand-held Geiger-type radiacmeter. By the use of sampling techniques the wide dynamic range of gamma intensities between 1 millirad/hr and 500 rads/hr is directly measurable. The basic instrument features a non-jamming circuit and provision has been made for operation within a wide range of temperatures. Low power requirements enable the IM-145 to operate with two BA-30, 1-1/2 volt flashlight cells for a period of sixty hours. The non-jamming feature and automatic scale-changing meter makes gross errors impossible. A nearly linear scale and provisions for checking batteries and circuit operation add to the ease of operation.

This equipment will complement the current tactical survey meter in the field and be useful in decontamination processes.

Completion of engineering design tests is expected by September 1963. Coordinated test plan meeting is scheduled Jan 64. Service test (5 models) scheduled Jun 64.

6. Radiation Detection and Alarm Set AN/FDR-2

The AN/FDR-2 is an equipment for use in continuous reading and recording of the intensity of gamma radiation at fixed installations. The AN/FDR-2 will consist of gamma-radiation detectors mounted at appropriate locations and connected by cable or wireless to an underground central control panel and indicating unit. The equipment operates over a cable length of at least 2700 feet and greater if possible. The gamma detectors and associated electronics will be capable of measuring gamma rates over a range from background to 5000 r/hr. The radiation intensity will be displayed on a meter-type instrument for direct readout and also will be recorded.

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The system will provide a means for continuous reading and recording of radiological contamination resulting from a nuclear detonation within the vicinity of underground military installations, without subjecting personnel to the hazardous conditions which may prevail outside the protected area.

Comparison studies of commercial and recently developed military instruments are now in progress for application to this task. Three types of detectors, the CONRAD type, the floating-grid-type, and the solid-state-type detectors are now being evaluated for performance, reliability, and economy.

7. Radiac Calibrators AN/UDM-2(XE-2), AN/UDM-2(XE-1), AN/UDM-4

The AN/UDM-2(XE-2) is a calibration device utilizing a radioisotope as the source of ionizing radiation. It is designed to calibrate all Army standard radiac instruments. Calibration is accomplished by exposure of the detecting elements to radiation in a contact geometry.

The AN/UDM-2(XE-1) is a laboratory-developed non-isotopic calibration device. This model utilizes a portable industrial x-ray generator as the source of ionizing radiation. The tube head is enclosed in a shielded enclosure which attenuates the external surface radiation to less than 0.5 mr/hr when operated at maximum output. Calibration is accomplished by exposure to the incident x-ray beam. The need for jigs or fixtures is eliminated by a unique x-y table adjustment mechanism. The x-ray device also has the potential of being adopted for use as a neutron calibrator.

The AN/UDM-4 is a calibration test set consisting of a certified 1-mg radium standard and precise standard measurement instruments which will assure measurement accuracy in areas where primary standard free-air calibrations are not available.

Calibrator Set AN/UDM-2 will be a rugged, tactical equipment capable of providing accurate fields of radiation.

Four models of the AN/UDM-2(XE-2) are planned to be available for laboratory tests in July 1963.

One model of the AN/UDM-2(XE-1) is planned to be available for laboratory tests in June 1963.

One model of the AN/UDM-4 is presently available for laboratory testing.

An evaluation of the two models will be made at "in-process review" in September 1963 in which a choice will be made for S/T development. Five service test models will be purchased for service test in September 1965.

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AIR FORCE RADIAC INSTRUMENT DEVELOPMENT PROGRAM

Summary of Mr. Murphy's Remarks to PRI

Although the contract with Bendix Corporation has been underway for two years, we still don't have a tactical SEMIRAD self-indicating dosimeter. This is not because of a lack of effort on the part of Bendix but because of the great difficulty encountered when one attempts to contain a hydrogenous plastic in the vacuum required for a SEMIRAD [illegible] 10^{-4} [illegible]

Work on containing hydrogenous plastics is maddeningly time-consuming. One cannot simply put a sample in a vacuum bottle today and tell tomorrow whether it is suitable for use in SEMIRAD. Consequently, much of this work has required that samples be individually packaged in a vacuum container and that these samples be put aside to outgas over a period of three months. So far the most promising candidate for the emitter of the dosimeter is (by coincidence) "Bendix Amber".

Benidx Amber is Bendix's Trade name for a variety of polystyrene which has an extremely high electrical resistance. This plastic is the material which Bendix uses as insulation in their production dosimeters. This is also the material that Bendix is using as insulation in SEMIRAD.

A few SEMIRAD using Bendix Amber have been built. Although these dosimeters are <u>not</u> rugged, reliable, military dosimeters, they are, however, working self-indicating laboratory instruments. Recently Bendix personnel exposed these SEMIRAD on Godiva II (SPRF). Although the results between dosimeters were [illegible], the results for each dosimeter showed no dose rate dependence at all. As far as I know, the neutron to gamma sensitivity of these SEMIRAD was found to be approximately 1/3 to 1. Although it is a temptation for me to say, "Well! Based on Dr. Mobley and Dr. Quaife's presentation, which stated that the tentative "RBE" of whole-body fast neutrons on sheep appears to be 1/3, we have a REM-dosimeter." - a response of 1/3 to 1 just isn't satisfactory for a neutron dosimeter. It appears that this low neutron sensitivity is the result of using an emitter which is too thin to permit equilibrium of the protons.

A new contract for another year-and-a-half development contract with Bendix is currently being negotiated. This contract, which is being jointly supported by the Army and the Air Force, should result in prototype SEMIRAD which are sufficiently rugged for technical military use. These dosimeters will also have a neutron to gamma sensitivity more nearly equal to 1 to 1. If the dosimeters don't encounter unforeseen bugs, a third contract should result in SEMIRAD suitable for tactical use.

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Incl 4

Summary of Capt Harris's Remarks to PRI

The Air Force Systems Command has reorganized the research and development activitites located at the Air Force Special Weapons Center, Kirtland AFB, New Mexico, into a new organization called the Air Force Weapons Laboratory. The Weapons Laboratory, abbreviated AFWL, reports to the Research and Technology Division of Systems Command.

1. The Air Force Weapons Laboratory has assumed direction of the Nuclear Aerospace Research Facility, a nuclear reactor and research complex operated by General Dynamics/Fort Worth.

Of approximately three dozen varied research programs to be conducted at this facility during FY 64, three are directly related to radiac instrumentation.

a. Development of improved readout for pulsed radiation dosimeters. The intended development is a capability to sample a single pulse traveling down a delay line with diodes and store the information. Resolution in the nanosecond range is desirable.

b. Solid State Detector Research. This is a slightly misleading title as the purpose of this research is development of inorganic scintillation phosphors with extremely rapid decay times. Under high pressure scintillation decay times on the order of 10^{-11} sec are possible.

c. Detectors for Use at Cryogenic Temperatures. The Air Force is interested in storage of cryogenic materials in space, and in the effects of radiation on such materials. To measure effect implies measurement of dose. One other item was mentioned as a possible concept for investigation, that being possible shielding of spacecraft from electrons by high intensity electromagnetic fields.

2. In addition to SEMIRAD development covered by Mr. Murphy, the Air Force is currently conducting three other contractual development efforts.

a. MGTS, a multiple station remote area dose rate detector system which communicates with telemetry. As presently conceived the system will have ten remote stations, a ten to twenty mile communication range, a 10 mr/hr to 5,000 r/hr ion-chamber detector and will employ pulse rate repetition to encode the dose rate. The purpose will be to enhance base reaction time and capability to fallout.

b. A wide range Beta Gamma Survey Meter. A lightweight, portable survey instrument to replace presently USAF standardized low and medium range survey meters (AN/PDR's 27, 39 and 43) and provide capability up to 10^4 rad/hr should such be necessary. The beta windows will total approximately 16 sq. in.

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c. The development of the PP-3679/U(XV-1) prototype piezeo-electric pocket dosimeter charger is nearing completion. Prototypes were demonstrated and made available to the Army, Navy and OCD representatives. Minor modifications will be made and a specification prepared. The instrument contains only one moving part.

3. In-House efforts planned for the coming months include a small scale parallel effort in determining "error of the operator" and studies of the effectiveness of shielding materials as predicted by various computer codes.

OCD RADIAC PROGRAM
By R. B. Martin, OCD

A general review of the status of radiological instrument development and related programs was presented. Direct distribution of OCD reports is made to Panel members and additional copies are available through the Defense Documentation Center.

The following instruments have essentially completed development and are being purchased as standard items for the first time:

CD V-794 Calibrator (Lionel) 100 units
CD V-711 Remote Sensor Shelter Meter (Nuclear Chicago) 200 units
CD V-781 Aerial Survey Meter (Nuclear Chicago) 1250 units
CD V-717 Remotable Survey Meter (Victoreen) about 100,000 units
OCD-D-101 Geiger Detector (Lionel) about 100,000 units

It was also noted that about 1,000,000 Standard CD V-742 Dosimeters were being purchased from Bendix.

The following general trends in monitoring and research were noted:

1. It appears for the first time that remote type instruments may be required with ranges to 10,000 r/hr.

2. OCD Research for instruments is expected to continue at the half million dollar per year level.

3. Research for instruments is being centralized in fewer contractors with larger projects.

4. A new generation of standard instruments is planned for development.

5. Field test quantities for plastic dosimeters, Piezo electric chargers and other promising new devices may be purchased later in the year.

6. Pilot installations of a ground-based or high speed aerial monitoring system may be undertaken.

7. OCD has no basic instrument requirement to measure neutron exposure, although it was noted this could change with changes in weapon design or with the implementation of a blast shelter program.

It was suggested that completely standard items can be established for general civil-military use in some cases. The quartz-fiber dosimeter in certain ranges was cited as a realistic candidate for full standardization. Large volume procurements for all users could produce savings, particularly for those who only need a few thousand items per year.

It was noted that Carl Siebentritt had been able to effect several improvements in the production quality assurance programs and that he is prepared to discuss the inspection and maintenance problems in depth if the committee desires.

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